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High Speed FSK Ultra Wide Band Transmitter

[1]Grace Paul N.
[1] PG student, GCEK
[1]gracepaul.n@gmail.com

***Abstract*— Ultra Wide Band (UWB) technology is a developing wireless technology which promises high data rate short distance communication. In this paper, propose an advanced method for generating UWB signal for many UWB related applications. Important area of application is Wireless Local Area Network (WLAN). The basic idea of the work is to develop pulses of nanosecond range for the UWB transmission and transmit using Frequency Shift Scheme (FSK) modulation scheme. Simulation of the transmitter section is done using High Frequency System Simulate (HFSS) tool. A micro-strip patch antenna is simulated for the transmission of signal, which gives maximum radiation in the transmitted signal frequency.**

***Index Terms*—FSK, Gaussian filter, HFSS, Impulse Radio (IR) Technique, Orthogonal Frequency Division Multiplexing (OFDM), Patch antenna, S-parameter, UWB, Voltage Standing Wave Ratio (VSWR),**

I. INTRODUCTION

Ultra wide-band (UWB) communications related systems are generally defined as systems with large bandwidth. Such a large bandwidth gives specific advantages with respect to signal robustness, information transfer speed, and implementation simplicity. The history of UWB reaches back to the 19th century (e.g., Hertz's experiments using spark-gap transmitters), and enabled these commercial use of UWB systems [1]. UWB has the potential to become the standard wireless unlicensed, short range, high speed network technology of the future. It started gaining momentum from 2002, when the Federal Communications Commission (FCC) opened the door for commercial development. Consequently, research in UWB has grown dramatically recently. The spectral mask of UWB system is given in the Figure 1.

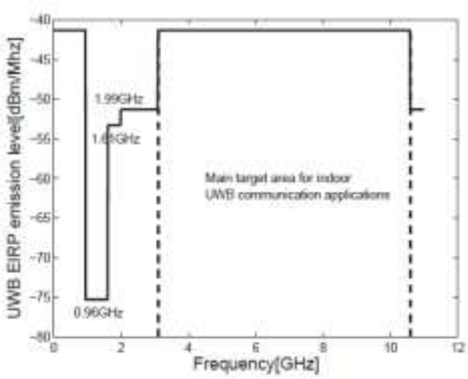

Figure 1: Spectral mask of UWB system

The high bandwidth (7.5 GHz in the US) ranges from 3.1GHz to 10.6GHz, makes the propagation through walls and other materials possible [2]. License free transmission of UWB is allowed from 2002 onwards provided the PSD is below -41.3 dBm. The short duration of the pulses makes UWB systems immune to multipath and jamming, which makes high data rates possible (up to 1 Gbps). This feature also makes accurate positioning possible.

Current UWB systems are mainly based on two basics: Orthogonal Frequency Division Multiplexing (OFDM) or Impulse Radio (IR) [1]. OFDM may be able to provide a robust high data rate solution, but this comes at the expense of circuit complexity and power consumption due to the requirement of digital signal processing. IR technique is better than this and that is for low duty cycle, high data rate and high energy efficiency. For this system, information is encoded in the form of narrow pulses, occupies small fraction of symbol period.

Nowadays increase the need of mobile communication and the development of large number of systems, the designing of broadband antennas to cover a wide frequency range is very important [3]. The design of an efficient wide band small size antenna for recent wireless applications is a major challenge. Micro-strip patch antennas have found extensive application in wireless communication system such as low profile, conformability, low-cost fabrication and ease of integration with feed networks [4].

IR UWB combined with FSK modulation scheme is proposed for the UWB transmitter. The importance of FSK modulation is to eliminate the pulse width and amplitude constraints of the transmission [1]. And also proposed a simulation of patch antenna which radiates maximum in the centre frequency of the signal used to transmit. Simulation is done using more suitable software HFSS.

This paper is organized as follows: section II gives the idea about proposed system and working principle of the transmitter. The UWB system simulated results of the work explained in section III. The paper concluded in the section IV.

II. PROPOSED SYSTEM

a. Basic Block Diagram

The proposed system contains three important sections for the designing of UWB transmitter and these are: Pulse generation, Modulation with binary data, and Pulse shaping. The simple block diagram is given as in the Figure2. The final section is the micro-strip patch antenna used for the transmission of the UWB signal.

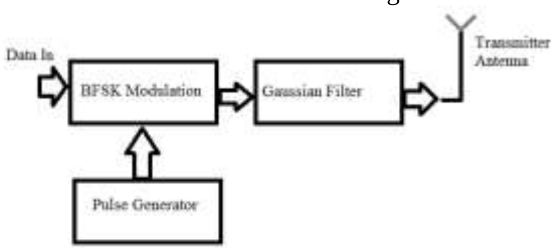

Figure 2: Basic block diagram of the UWB transmitter

b. Pulse Generation

The most important step in the transmitter section is the pulse generating module [5]. Here high frequency short duration pulses generate by using some suitable circuits. There are several circuits are using to generate pulses and in this system pulses are produced by designing parameters in the HFSS pulse generator block. Pulse tool box in HFSS is given in the Figure 3.

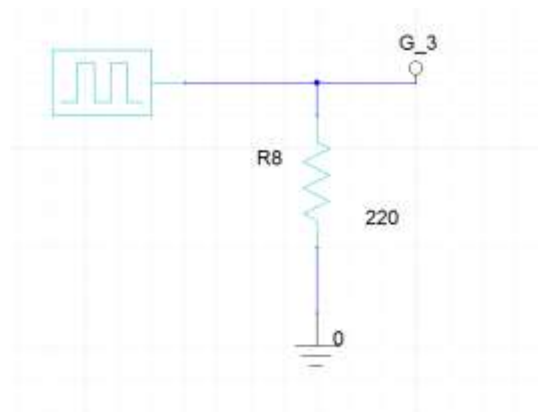

Figure 3: Pulse generating block using HFSS

R8 is the load resistance and G_3 connected as the output port. There are different parameters to be designed for getting proper short duration pulses.

$$\text{duty cycle} = \frac{T}{Period}$$

$$\text{sampling rate} = \frac{N}{duration}$$

where T is the ON time of the input and N is the number of samples

c. Binary Frequency Shift Keying

In Binary Frequency Shift keying (BFSK) [6], the frequency (f1 and f2) of constant amplitude carrier signal is switched between two values according to the two possible message states corresponding to a binary 1 or 0. Depending on how the frequency variations are imparted into the transmitted waveform, the FSK signal will have either a discontinuous phase or continuous phase between bits.

BFSK circuit is given as in the Figure 4. The basic idea behind the modulation scheme used here is taking the product of the signal with the pulse generated. The circuit diagram proposed is given as, two multipliers which multiply the input signal and two set of pulses. Two set of pulses generate by the set of pulse blocks of HFSS and is given to the corresponding multipliers together with input data and add the results of two multipliers using adder. Final modulated output is taken from the port G_8.

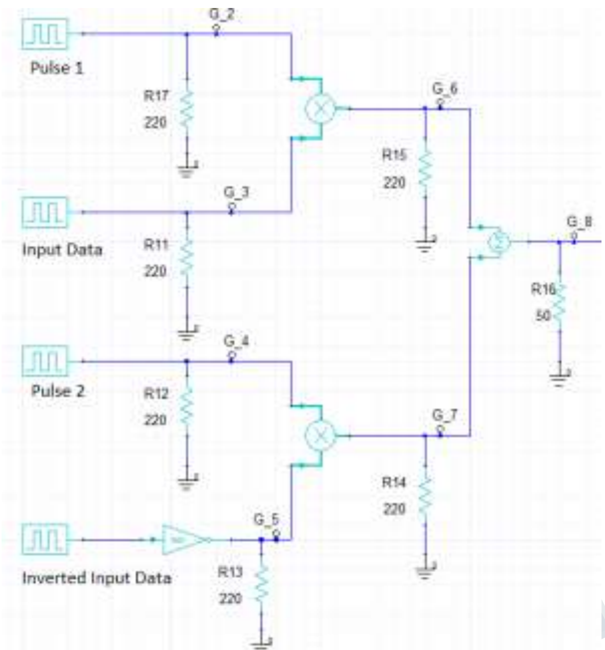

Figure 4: BFSK modulation module

d. Gaussian Pulse Shaping Filter

Transmitting a signal at high modulation rate through a band-limited channel can create Inter Symbol Interferences (ISI). As the modulation rate increases, the signal’s bandwidth increases. When the signal’s bandwidth becomes larger than the channel bandwidth, the channel starts to introduce distortion to the signal.

This distortion usually refereed itself as ISI. To improve the signal from this issue, usually use a pulse shaping filter and here use a Gaussian pulse shaping filter designed by using HFSS software. The designed filter is shown as in the Figure 5. This is done using a series connected inductors and capacitors by designing the values of corresponding capacitors and inductors. The output of filter is taken from the output port G(9). The resister R55 is used as the output resister and is taken as 50Ω.

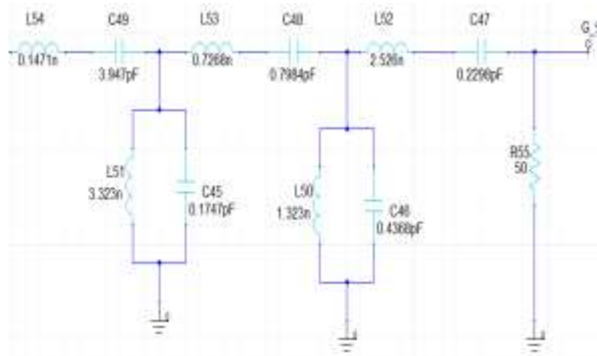

Figure 5: Gaussian filter circuit

A Gaussian band pass filter designed using HFSS software by giving the frequency range 3.1 GHz to 10.6 GHz, which is the frequency band of UWB range and set the center frequency as 7.5 GHz.

E. Micro Strip Patch Antenna

Micro-strip patch antenna is a simple designable antenna used for short duration applications mainly for wireless communication [7]. It has a ground plane on one side of the substrate. The substrate can be Benzocyclobuten, Rubber, Quartz, etc. The ground plane on one of the sides is a conducting material, which can be Copper or Silver, Aluminum, etc. On the other side, we have a patch, which is smaller than the substrate and feed with a Micro strip line. The directivity is independent of substrate thickness. The substrate can be of different shape, ie., circular, rectangular depending on the application. The simulated micro strip patch antenna using HFSS is given in the Figure 6.

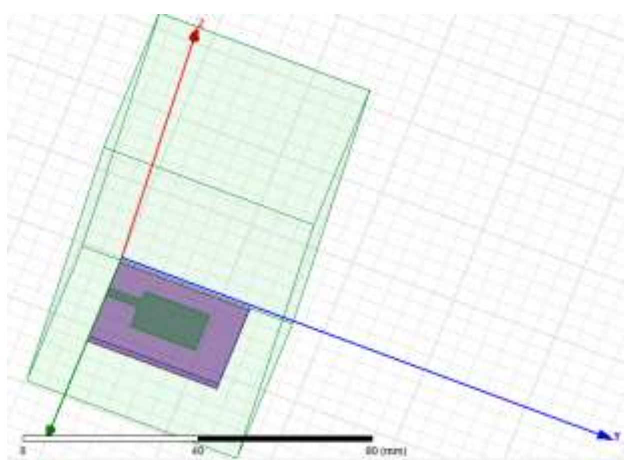

Figure 6: Micro strip patch antenna

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The designing of the antenna having some steps and is given as:

1. Initially obtain the width of the patch

$$W = \frac{c_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$$

where,

c_0 = 3x108m/s is the speed of light
f_r = 8GHz is the required frequency
ε_r = 4.4 is the dielectric constant of the used substrate material

2. Find effective parameter dielectric constant

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{(-1/2)}, \frac{W}{h} > 1$$

where,

h = 1.6 mm is the height of the board selected

3. selected Find the second effective parameter ratio ratio

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)}$$

where,

ΔL is the parameter related to length of the patch

4. Get patch length

$$L = \frac{c_0}{2f_{r\sqrt{\varepsilon_{reff}}}} - 2\,\Delta L$$

Table 4.1 gives the calculated parameters of the patch antenna for the respective frequency. This designing done using the equations given above.

Sl. No.	Parameters	Values	Units
1.	Frequency, f_0	8.5	GHz
2.	Dielectric constant, ε_r	4.4	No unit
3.	Substrate height, h_s	1.60	mm
4.	Thickness of conductor, t	0.05	mm
5.	Width of patch, W_p	12.45	mm
6.	Length of patch, L_p	16	mm
7.	Length of ground, L_g	32	mm
8.	Width of ground, W_g	28.1	mm
9.	Width of feed, W_f	2.46	mm
10.	Input impedance, Z_c	50	ohm

Table 1: Parameters of the simulated patch antenna

III. RESULTS AND DISCUSSION

Pulses are the basic idea need for the UWB communication. In this work, BFSK modulation scheme used for modulation in the UWB transmission. BFSK requires two different pulses, one transmit in the time of data '1' and other transmit for the data'0'. For the communication in the UWB range needs narrow pulses of nanosecond range. Here use a 1ns pulse and 10ns pulse for data '1' and '0'. 1ns pulse is given in the Figure 7 is used for data '1' and Figure 8 shows the 10ns pulse.

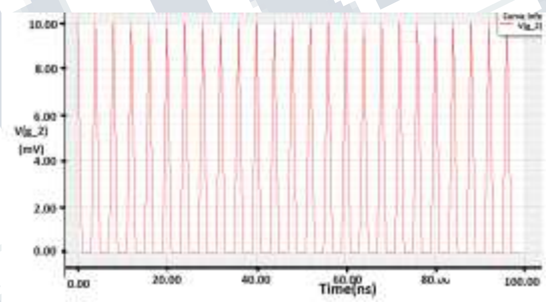

Figure 7: Pulse of 1ns

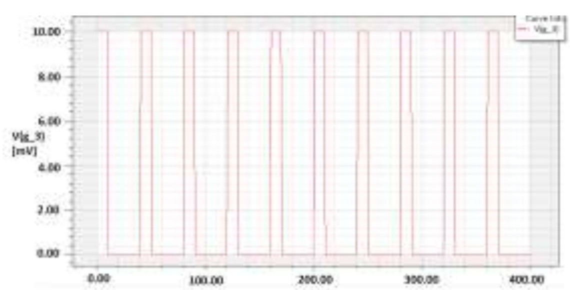

Figure 8: Pulse of 10ns

Next section is the simulation of the BFSK circuit. Modulation is done using two multipliers and an adder which initially multiply the input data signal and the pulses generated and then add two multiplier outputs. The output signal indicates the pulses of 1ns is transmitted for the data

'1' and pulses of 10ns is transmitted for data '0'. Next is to design the pulse shaping block parameters as per the need. It is given as in the Figure 4 and the corresponding output signal in the Figure 9.

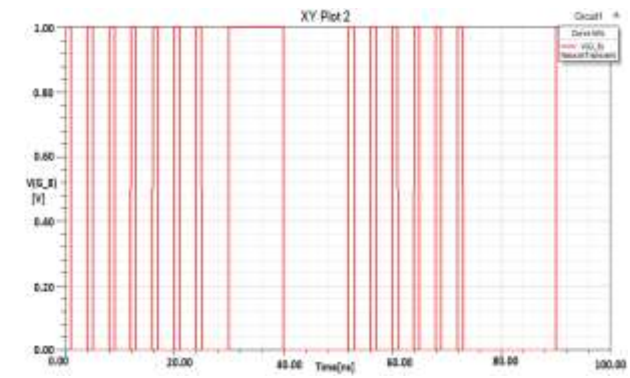

Figure 9: BFSK modulated output

Next section of the simulation is the pulse shaping filter and here use a Gaussian filter and the resultant waveform given as in the figure 10. In this output, can see a fixed number of Gaussian UWB pulses transmission for data '1' and '0'.

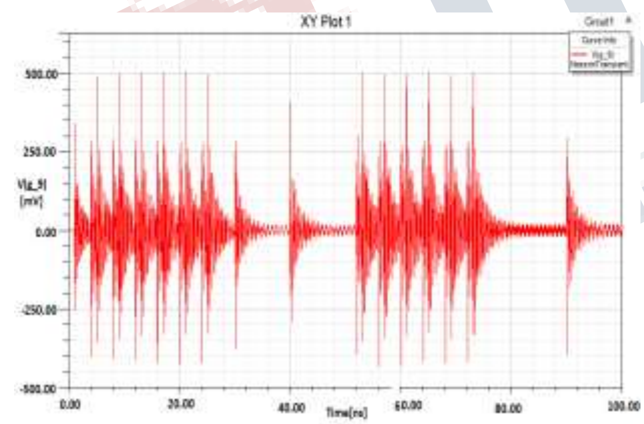

Figure 10: Transmitter output

The antenna characteristics determined using S-parameter [7], [8], and the S- parameter of the simulated patch antenna is given in the Figure 11. Here, maximum deep related to the maximum radiation and in this simulation maximum radiation needs in UWB frequency range (3.1 GHz-10.6 GHz). 9.5 GHz frequency gives maximum radiation.

In s-parameter plot, taking frequency on X axis and S11 in dB on Y axis. S11 is the reflection coefficient and is minimum for maximum radiation. For the proper operation of the antenna the minimum reflection coefficient lies below -10dB. In this work, maximum radiation in the frequency 9.5kHz and corresponding S_{11} is -30dB is representing comparatively better radiation performance.

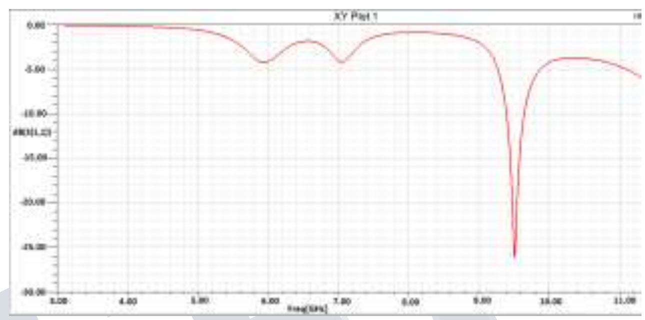

Figure 11: S_{11} parameter curve

3D rectangular plot of the S-parameter curve also can be plotted using HFSS software and is shown as in the Figure 12. In the Z direction takes S11 in dB by varying frequency simultaneously on both X and Y direction.

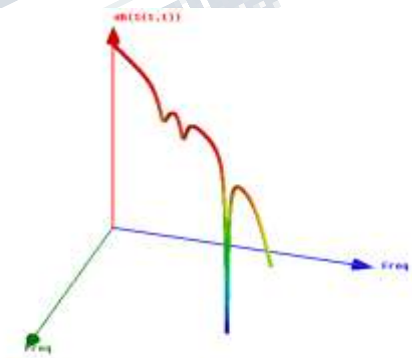

Figure 12: 3D plot of S_{11} parameter curve

The patch's radiation [7], [8], at the fringing fields results in a certain far-field radiation pattern. This radiation pattern shows that the antenna radiates more power in a certain direction than another direction. The antenna is said to have certain directivity. This is commonly expressed in dB. According to the parameter φ get different radiation pattern. For a good antenna simulation results in nearly similar radiation pattern when varying the angle values of φ. Giving parameters, elevation angle θ and azimuthal angle φ, can generate radiation patterns. In this infinite sphere, can vary the values all over the sphere, i.e., both can take any values within 0^0 and 360^0. The resultant patterns are given as in the Figure 13 to 16.

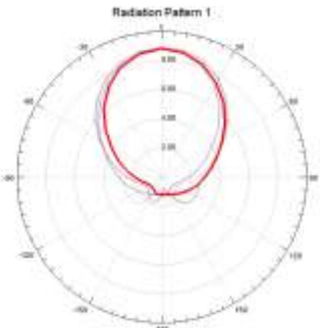

Figure 13: Radiation pattern for φ=0^0

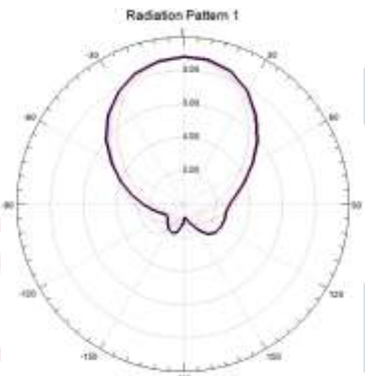

Figure 14: Radiation pattern for φ=90^0

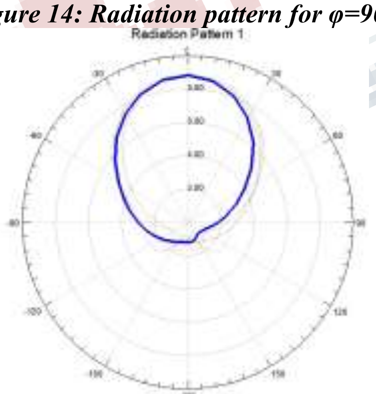

Figure 15: Radiation pattern for φ=180^0

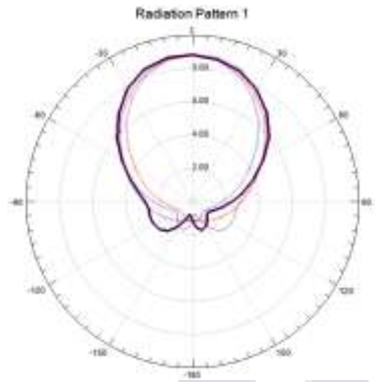

Figure 16: Radiation pattern for φ=360^0

Antenna gain is defined as antenna directivity [8], times a factor representing the radiation efficiency. This efficiency is defined as the ratio of the radiated power (P_r) to the input power (P_i). The input power is transformed into radiated power and surface wave power while a small portion is dissipated due to conductor and dielectric losses of the materials used. Surface waves are guided waves captured within the substrate and partially radiated and reflected back at the substrate edges. The antenna gain is shown in the Figure 17.

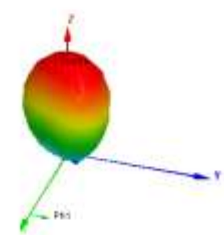

Figure 17: 3D polar plot of antenna gain

When a transmission line (cable) is terminated by an impedance that does not match the characteristic impedance of the transmission line, not all of the power is absorbed by the termination. Part of the power is reflected back down the transmission line. The ratio of the maximum to minimum voltage is known as Voltage Standing Wave Ratio (VSWR). High VSWR implies wastage of power. The resultant VSWR curve of simulated antenna is given in the Figure 18. The VSWR is always a real and positive number for antennas. The smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is delivered to the antenna. The minimum VSWR is

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 3, Issue 8, August 2016

1.0. In this case, no power is reflected from the antenna, which is ideal.

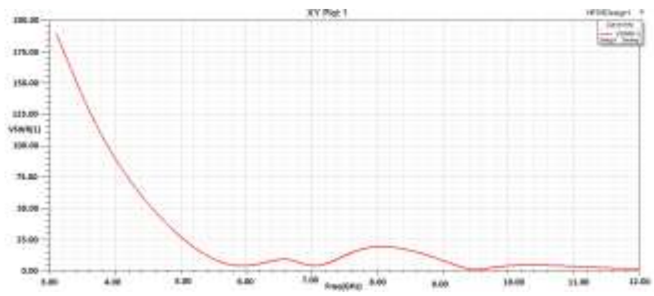

Figure 18: VSWR curve

IV. CONCLUSION

In this work, an advanced method for designing a high frequency FSK UWB transmitter is proposed and simulated. Different approaches exist in the same area and also seen different methods proposed by different authors. Then studied about the methods for generating UWB pulse in detail. Here use an FSK modulation for the modulation with binary input data. The pulse block in the HFSS tool box is used to generate UWB pulse. Finally we use a pulse shaping circuit for re- moving Inter Symbol Interference (ISI) over the transmission. The entire system developed for the frequency of nearly 9GHz, is also works in the UWB range. UWB pulses for the wireless transmission and FSK modulation scheme used is also have appreciable qualities over the another schemes such as high data rate, low transmission power and simple designing process. Simulation of micro strip patch antenna has also done and the corresponding radiation pattern and characteristic curves are plotted. The simulated antenna also works in the UWB frequency range.

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